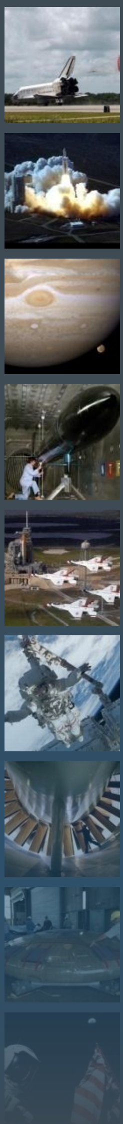
National Aeronautics and Space Administration



Breathe

Survival and the United States' Most Advanced Fighter Jet

Senior Management ViTS Meeting

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BACKGROUND

November 16, 2010, Joint Base Elmendorf-Richardson (JBER), Alaska: On a clear and quiet night, six United States Air Force (USAF) F-22A Raptor fighter jets departed from base to intercept and skirmish against four USAF F-16 fighter jets for an opposed air-to-ground attack training mission. The training mission went according to plan, but during the return-to-base (RTB) phase of the flight, one F-22A crashed. The pilot did not attempt an ejection and was killed in the crash.

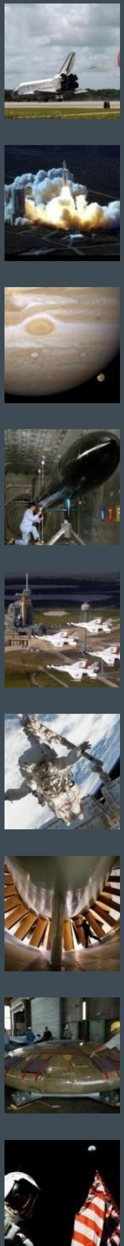
The Lockheed Martin/Boeing F-22A Raptor

- The F-22, introduced into United States Air Force (USAF) in December of 2005, is an air-to-air/air-to-ground, fifth-generation, single seat, twin-engine, supermaneuverable, superiority fighter utilizing state-of-the-art avionics, stealth, and supersonic cruise technology (Figure 1.).
- The mishap aircraft (MA) was properly inspected and maintained and had no history of reoccurring maintenance issues.


Figure 1.

The Mission

- At 6:17 p.m. Alaska Standard Time (AKST), the weather was clear with unlimited visibility and significant moon illumination over snow covered terrain beneath military airspace as the six F-22As departed from JBER.
- Frigid temperatures required Category III (Cat III) cold weather pilot gear: insulated and bulky flight suits and gloves. Night attack flying required night vision goggles (NVGs). This was the first mission of the season involving Cat III gear.
- The mission rated “High” according to USAF Operational Risk Management (ORM) analysis, due to night operations, a 20-min delayed takeoff for winds, and that it was the mishap pilot’s (MP’s) second active event for the day; however, the decision was made to continue.
- The F-22As successfully launched, completed maneuvers, and proceeded to return to base.



WHAT HAPPENED

Navigation and Collision

- At 7:39:57 p.m., the flight leader (FL) seeing the MP ahead of formation, directed the MP to return to a trail formation.
- The MP acknowledged in his last radio transmission. He initiated a climbing turn to rejoin, crossed FL's projected flight path, and then began descent into formation from approx. 52,000 ft. mean sea level (MSL) (Figure 2.).
- At 7:42:18 p.m., MA sensors detected a bleed air (hot compressed air used for auxiliary systems) leak in the center ducting from both engines. The MA's subsystem controller used the Environmental Control System (ECS) to isolate the center bleed system and commanded the ducts closed, stopping bleed airflow to ECS and thus all airflow to the on-board oxygen generating system (OBOGS).
- The MP would have immediately felt suffocated and would have struggled to breathe. Actual cabin altitude in the F-22A cockpit is unknown.
- The MP set throttles to idle, initiating a descent procedure until 7:42:45 p.m. (Figure 2.). There had been no pressure to the MP's oxygen mask since 7:42:37 p.m. For the next 8 secs, the MP made no control inputs. Passing through 19,000 ft. MSL, cabin pressure rose above nominal as the MA descended rapidly.
- At 7:42:53, the MP made a combination of stick and pedal inputs, initiating a 240-degree descending right roll at greater than 45 degrees per sec, rolling the MA inverted and plummeting down at a rate of -57,800 fpm (Figure 3.). There were no stick inputs and only very minor pedal inputs for the next 15 secs.
- At 7:43:24 p.m., the pilot pulled up, attempting a 7.4-g dive recovery at 5,470 ft. MSL. The pullout was initiated far too late to recover and the MA impacted the ground 3 secs later at a rate of -57,900 fpm, killing the MP.

WHAT HAPPENED

Figure 2. The MA performing a descending right hand turn to rejoin formation.

Figure 3. The MA position after MP stopped control inputs (no pressure to mask).

Figure 4. The MA inverted and plummeting with no control input from MP (no pressure to mask).

PROXIMATE CAUSE

The MP entered a 240-degree roll through inverted, and the nose down pitch attitude of the MA increased. Although a dive recovery was initiated, the MA impacted the ground, killing the MP.

UNDERLYING ISSUES

The Aircraft Accident Investigation Board (AAIB) ruled that human factors and control inputs were causal; ruling out sudden incapacitation.

Channelized Attention and Disorientation

- According to the OBOGS failure checklist, the MP was to activate the emergency oxygen system (EOS), but the EOS was never activated. The AAIB deemed it likely that when the airflow stopped, attention channelized on activating the EOS, delaying recognition of altitude and application of corrective actions.

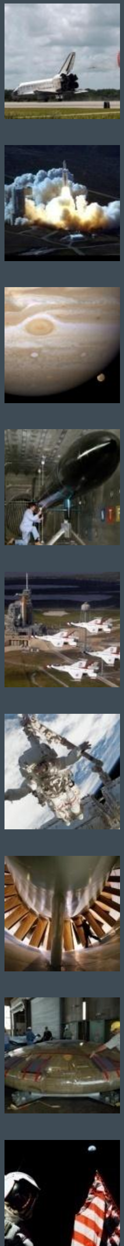
Personal Equipment and Ergonomics

- A CAT III gear and NVG cockpit maneuverability assessment revealed reduced mobility (Figure 5.). NVGs narrowed line of sight and interfered with visual scanning, requiring wearers to shift their torso while bracing against the cockpit to perform a scan. CAT III gear limited tactile sensation.
- Testers able to activate the small EOS pull-ring in CAT III gear and NVGs stated the 40lb-pull activation would be difficult and it was possible to drop the ring between the seat frame and cushion.

Figure 5.

Organizational Training Issues

- The MP had recently reviewed malfunction procedures. However, the training does not simulate physiological stressors that the pilot may have encountered (i.e., suffocation).



AFTERMATH

The Pentagon Inspector General investigating the Air Force investigation also deemed human error causal to the mishap. Civil legal action against the manufacturer resulted in changes to the design and location of the EOS activation mechanism.

The USAF investigation did not assess or validate design or training requirements as part of its scope. It verified aircraft and pilot performance as designed and as trained or qualified. USAF safety reports are written to prevent recurrence and are not generally released to the public.

RELEVANCE TO NASA

- From this, NASA can draw engineering and safety lessons. First, a vast array of personal protective equipment (PPE) is currently worn in conduct of NASA missions. The more unforgiving the environment, the more important it is to practice off-nominal tasks to perfection. Where is the off-nominal life-saving design margin, in redundant or robust engineering? To what extent has the user been considered in its design or acquisition? Does the PPE conform not only to the user but to the constraints of the workplace?
- Second, regarding user qualification and training: can the least-proficient user understand and exploit that full margin of safety on the worst day at work? There are at least three qualifiers to the “Yes I can” answer: yes, if I have the knowledge; yes, if I am physically capable; and yes, if I am proficient enough today at the skills needed today. Each of the three is a perishable commodity that needs checking for high-risk tasks regardless of any protective equipment involved.